ATMS SDR Lunar Intrusion Assessment and Mitigation Activities and Results

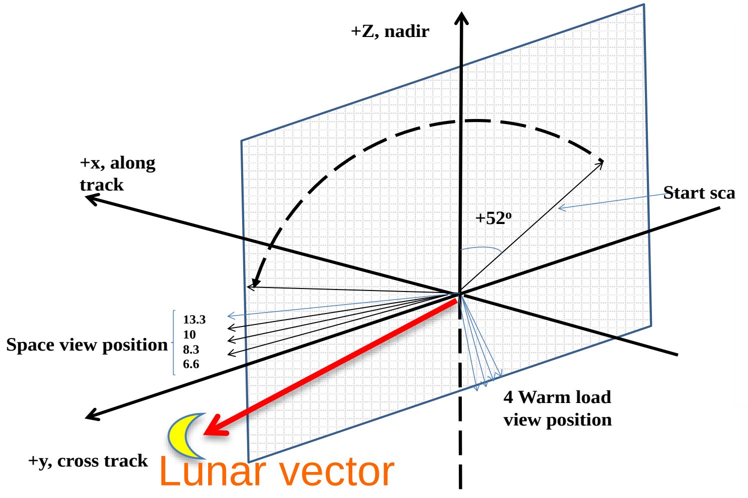
Hu(Tiger) Yang[1,3], Degui Gu[2], Fuzhong Weng[3], Ninghai Sun[3], Lin Lin[3]

1. Earth System Science Interdisciplinary Center(ESSIC), UMD
2. Northrop Grumman Aerospace Systems
3. National Environmental Satellite, Data & Information Service, NOAA

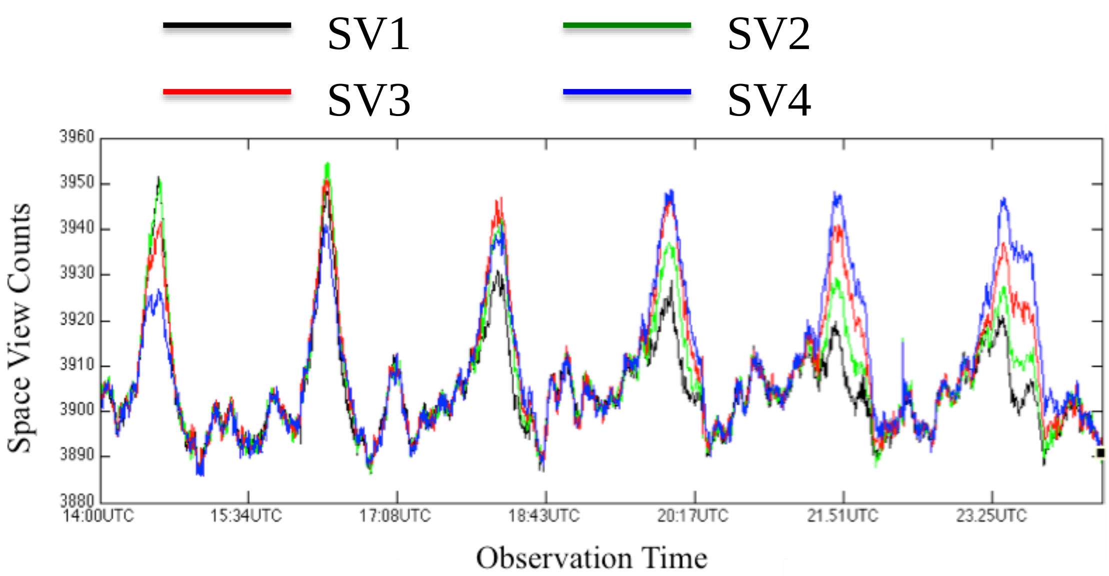
Impact of Lunar Intrusion (LI) on SDR Calibration

Illustration of Lunar Intrusion

Physical Temperature of the Moon: 120 ~ 380 K
Microwave Emissivity of the Moon : ~0.97



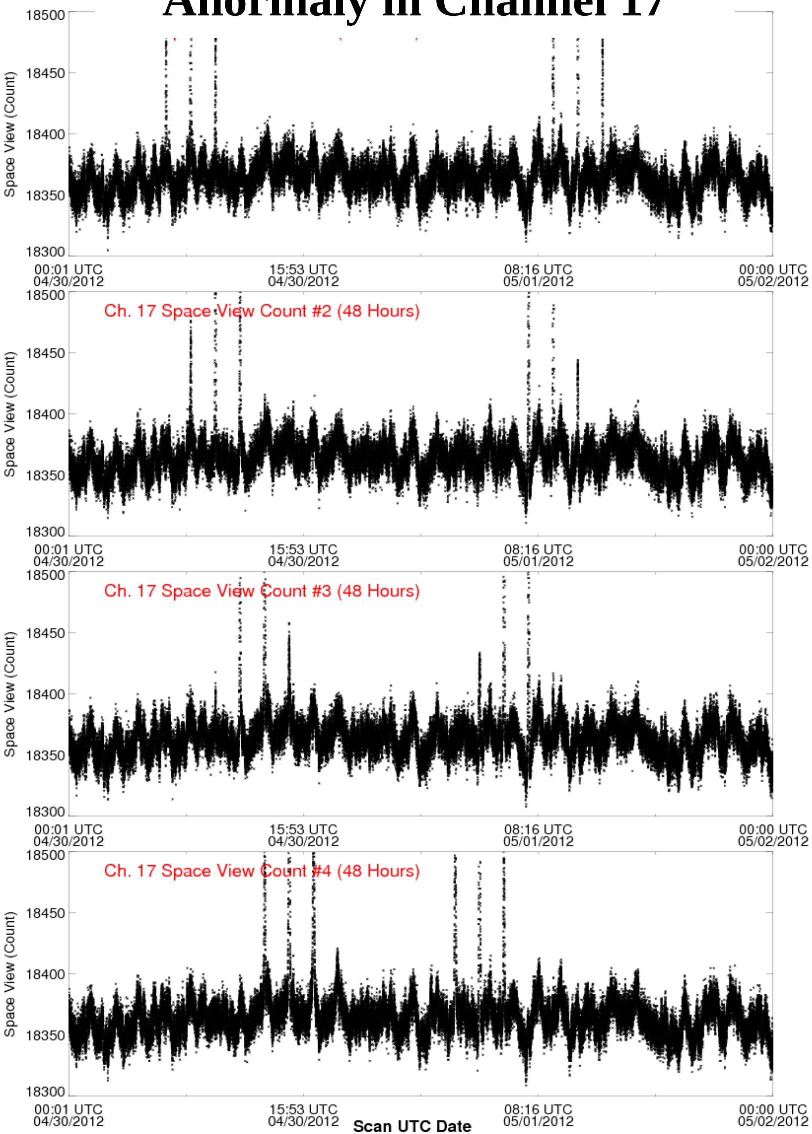
Cold Counts Anormaly Due to Lunar Intrusion



Cold calibration count from ATMS space view increases when the Moon intrudes the ATMS antenna field of view. This increase is referred to a lunar contamination since the cold calibration count is not matched with the specified cold space brightness temperature (2.73K). At lower frequency channels having a larger field of view (FOV), the cold count can increase by 40 counts(~1K). At higher frequency channels having a smaller FOV size such as G bands, the cold count anomaly can be as large as 400 (~20K).

ICVS Monitoring of LI Incidents

ICVS Monitoring of CV Anormaly in Channel 17



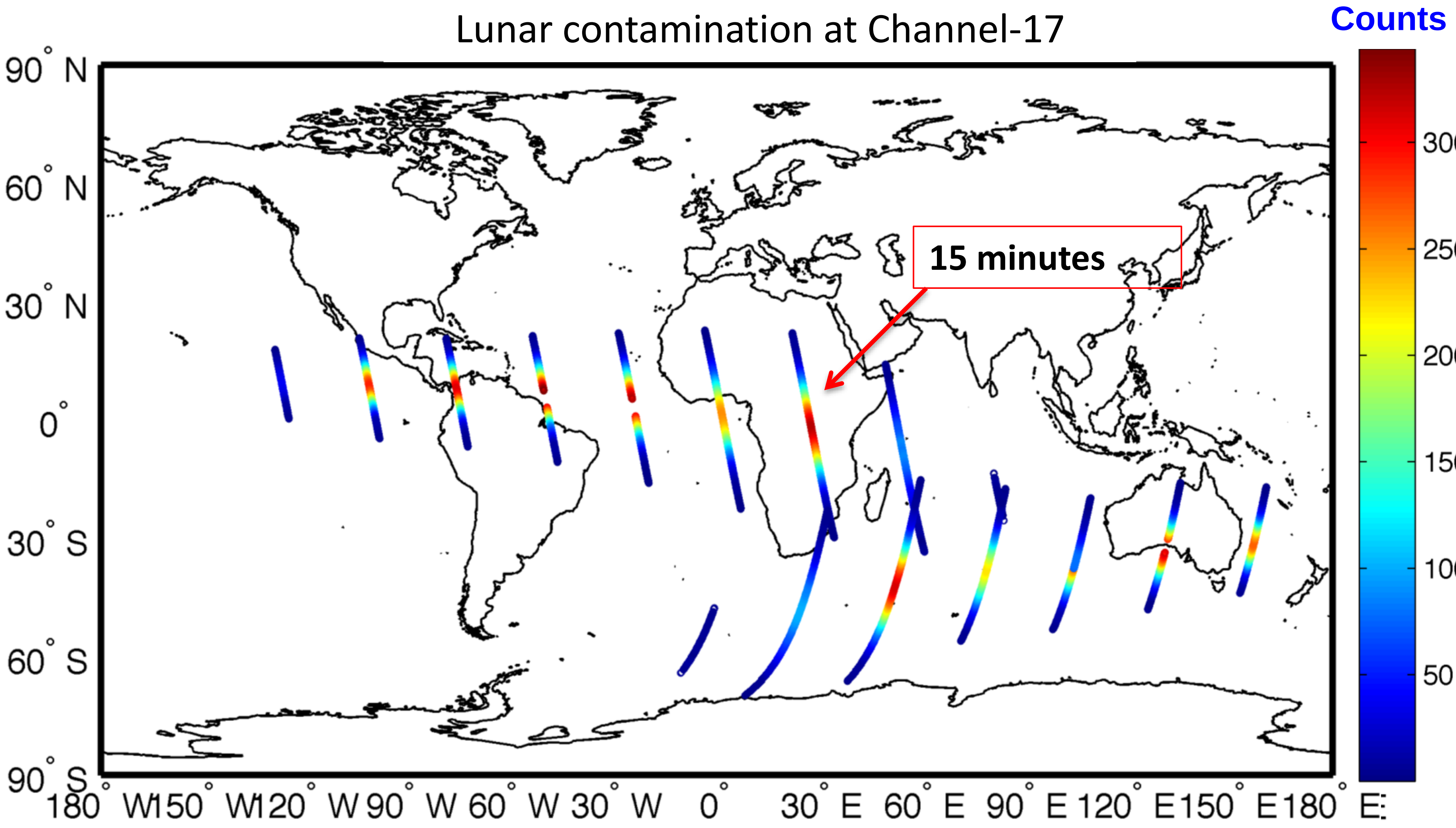
LI incidents since launch

Accident of Lunar Contamination	Lasting Time
December, 2011	Dec.03-05
December, 2011	Dec.09
January, 2012	Jan.02-04
April, 2012	Apr.01-02
April,2012	Apr.29-May.01
November,2012	Nov.22-23
December, 2012	Dec.21-23
January, 2013	Jan.20-21
March, 2013	Mar.20-21
April, 2013	Apr.19-20
May,2013	May.18-20
November, 2013	Nov.12

Global Distribution Feature of LI

Lunar contamination from UTC 14:00,Apr.19 2013 to UTC 01:00 Apr.21,2013

LI was observed and identified from the SV samples at different channels from the time it began entered the field of view (FOV) till it moved out of the FOV

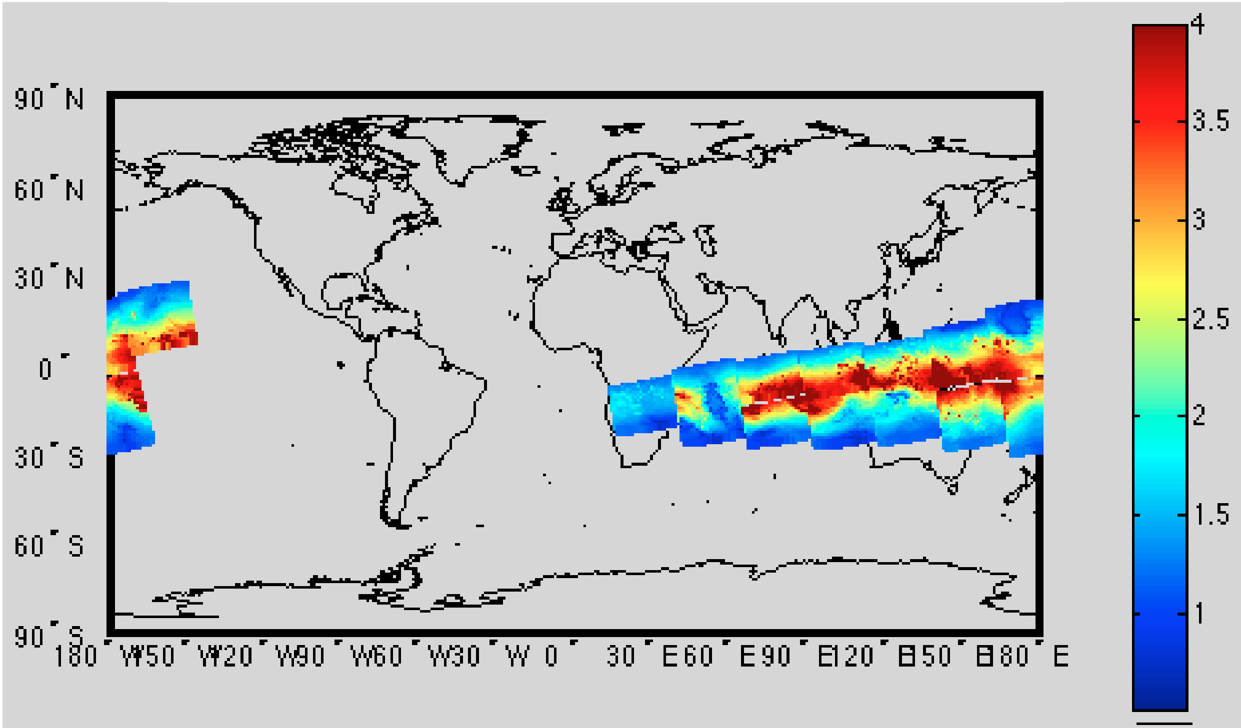


Impact of LI on SDR Calibration Accuracy

Bias is defined as antenna brightness temperature before and after lunar correction

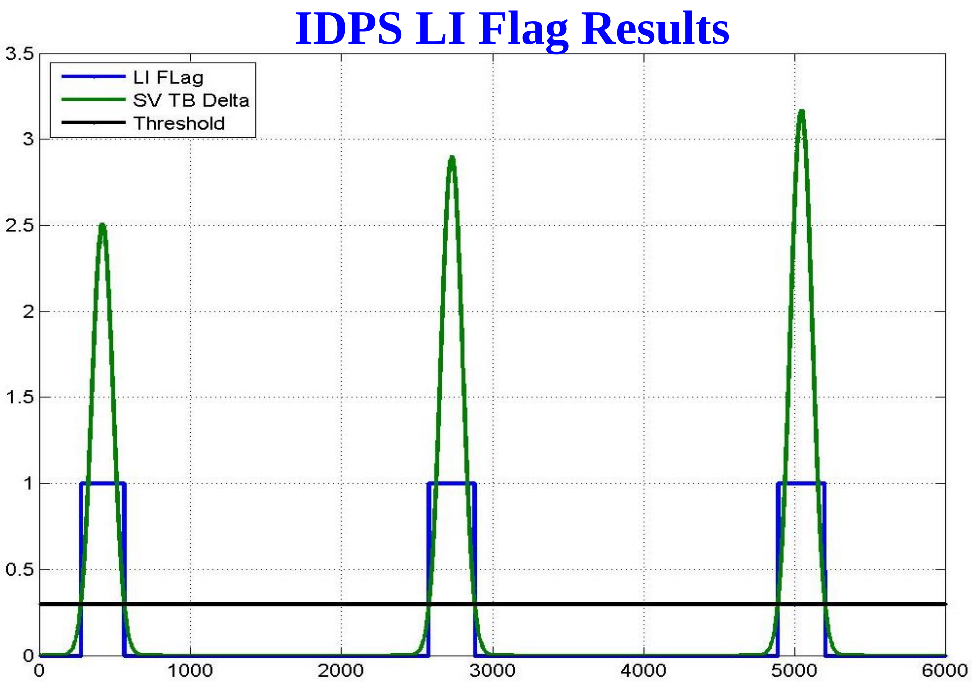
$$\Delta T_s = T_s' - T_s = \Delta T_{moon} - \Delta T_{moon} \cdot \left(\frac{C_s - C_c}{C_w - C_c}\right)$$

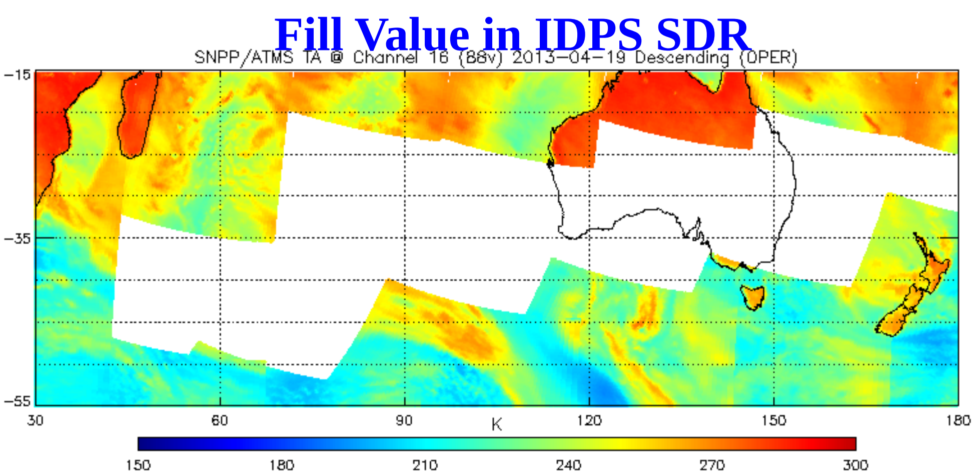
Bias at ATMS Channel 18



Impact of lunar contamination to antenna brightness temperature is channel- and scene-temperature dependent. As explained from the calibration equation, the calibration errors increase as scene brightness temperature decrease.

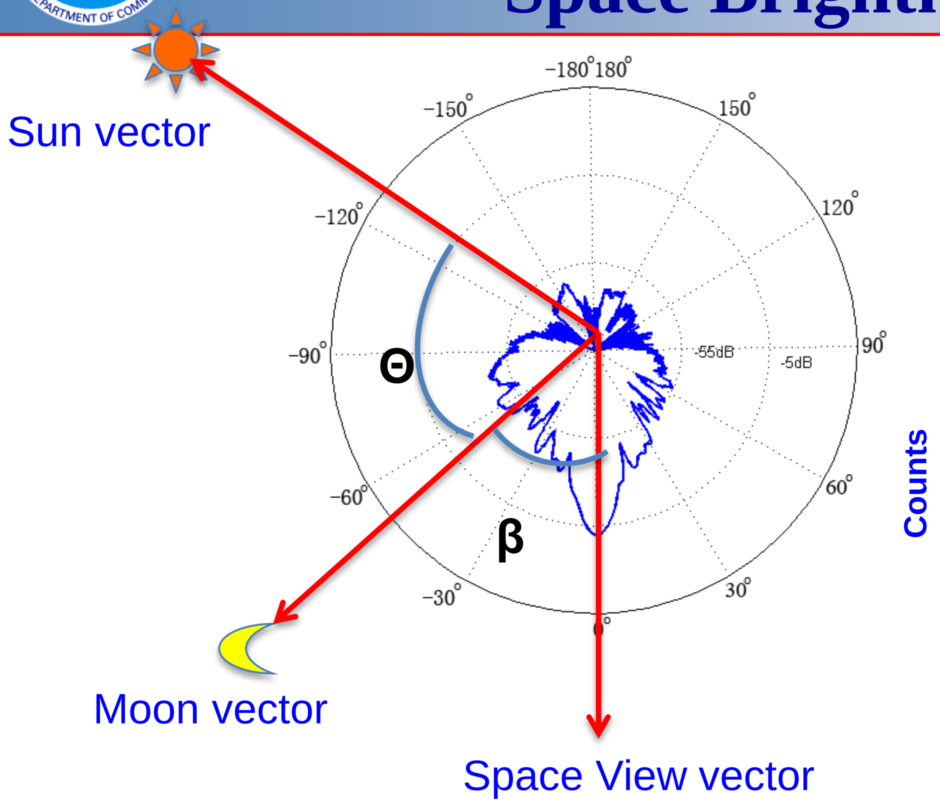
Current LI Flagging/Correction Status in SDR





- Lunar identification are based on the brightness temperature increment computed from model inherited from AMSU
- LI can be flagged correctly, the LI flag in SDR are correct
- LI correction is not implemented in current IDPS
- The QC check for SV samples are based on the consistency among the SV counts, which make the fill value not consistency with LI flag

Physical Modeling For LI Correction of Cold Space Brightness Temperature



- LI happens when $\beta' = \beta - \alpha_l \leq 1.25 \cdot \theta_{3dB}$
- Lunar contamination to the four space view counts are different.
- The increased brightness temperature due to the lunar contamination can be accurately identified and quantified from model.

Brightness temperature increment arising from lunar contamination can be expressed as function of lunar solid angle, antenna response and radiation from the Moon

Space view radiance increment

$$\Delta T_{moon} = G * \Omega * T_{moon}$$

Antenna response function:

$$G = e^{\frac{-(\beta' - \alpha_0)^2}{2\delta^2}}, \quad with\ \delta = \frac{0.5 \cdot \theta_{3dB}}{\sqrt{2 \cdot log2}}$$

Weights of the Moon in antenna pattern:

$$\Omega_{moon} = \frac{\pi\left(\frac{r_{moon}}{D_{moon}}\right)^2}{\iint G(\theta,\varphi)d\theta d\varphi}$$

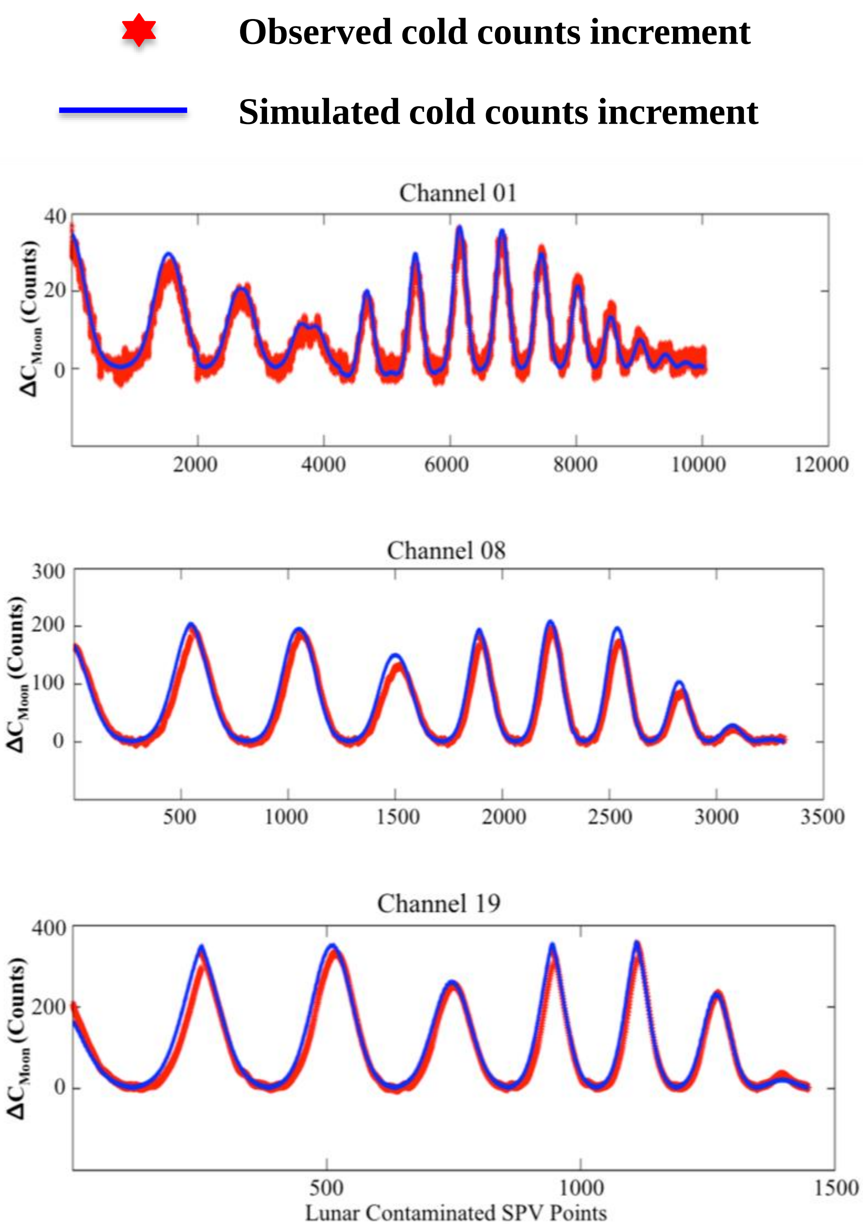
Brightness temperature of the Moon

$$T_{moon} = 95.21 + 104.63 \cdot (1 - cos\Theta) + 11.62 \cdot (1 + cos2\Theta)$$

Best fitted Parameters for LI Correction Model

Channel	α_0	δ	Ω_{moon}
1	-0.22	2.23	0.0050
2	-0.38	2.31	0.0053
3	-0.11	0.96	0.0257
4	-0.09	0.95	0.0255
5	-0.10	0.95	0.0258
6	-0.10	0.94	0.0259
7	-0.10	0.93	0.0261
8	-0.11	0.94	0.0262
9	-0.10	0.93	0.0263
10	-0.12	0.92	0.0275
11	-0.14	0.93	0.0277
12	-0.14	0.93	0.0277
13	-0.15	0.94	0.0276
14	-0.16	0.94	0.0277
15	-0.18	0.96	0.0281
16	-0.16	0.90	0.0287
17	-0.25	0.54	0.0913
18	-0.22	0.51	0.0900
19	-0.22	0.51	0.0897
20	-0.22	0.51	0.0894
21	-0.22	0.51	0.0898
22	-0.22	0.50	0.0895

Validation of Updated LI Correction Model



- In the two-point calibration equation, the cold counts increment arising from LI can be expressed in terms of the channel gain and the increased cold space view brightness temperature

$$\Delta C_{moon} = \left[\frac{C_w - C_c}{Tw - (Tc + \Delta T_{moon})}\right] \Delta T_{moon}$$

- Model prediction agree well with observed cold counts increment
- Physical model will be used for correction of cold space view brightness temperature

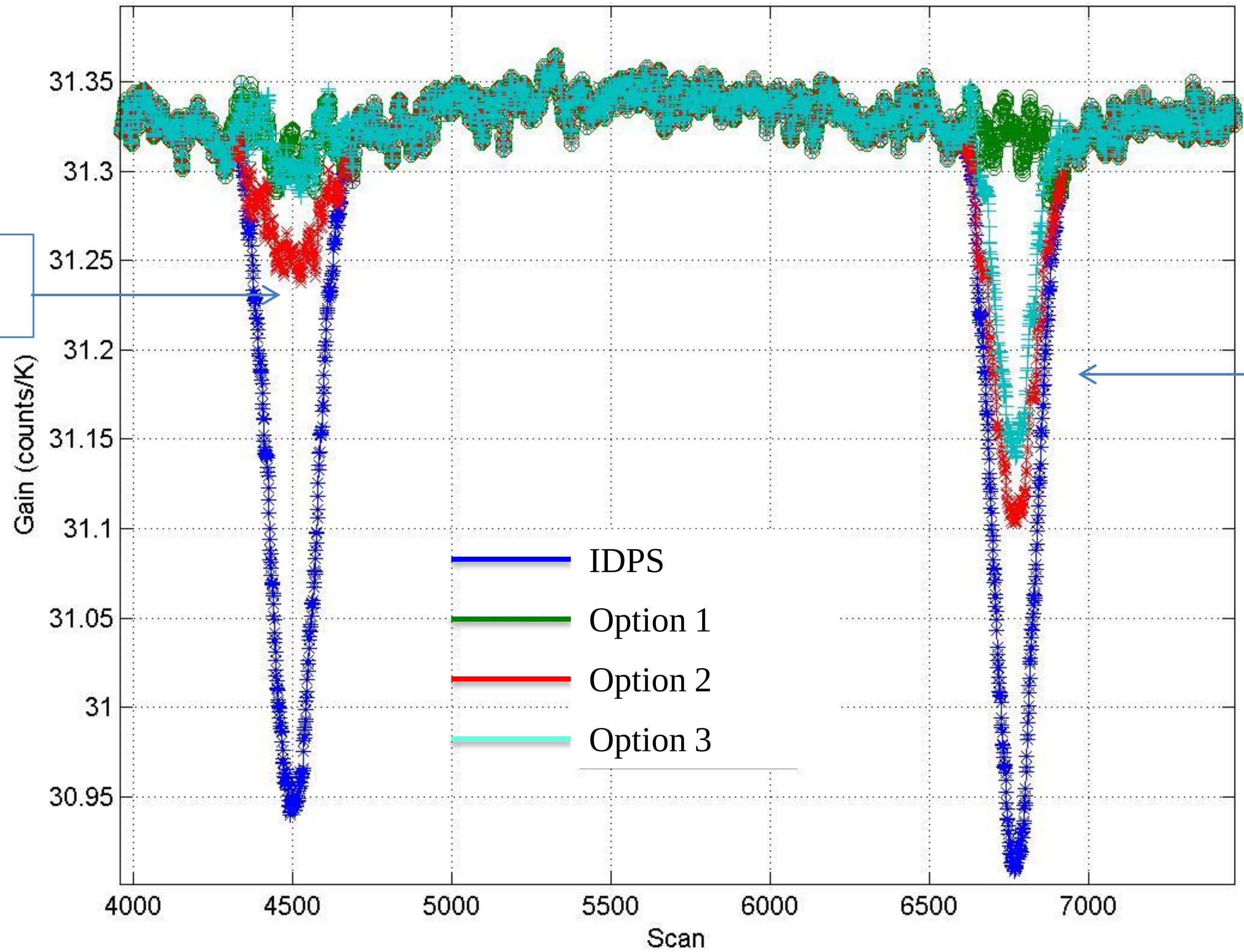
Lunar Intrusion Algorithm Update Options

Different LI correction algorithms were tested in off-line calibration system, the one with better correction results and easy to be adapted to current calibration scheme was selected for use in IDPS

- Option 1: detection based on model and correction based on nearest "good" cold counts
  - Detection will be based on the geometry model as currently implemented in the operational code
  - <u>Additional change: correct contaminated cold counts using the most recent cold counts that are NOT affected by LI, instead of replacing them with fill values; correct contaminated cold space brightness temperature using updated physical model</u>
    - Allow the consistency check
    - Prevent data gaps
  - Works well in all occasions
- Option 2: detection and correction based on selected cold counts
  - Detect lunar intrusion by checking the cold counts
  - Replace contaminated data with uncontaminated cold counts
  - Works well except when all four SVs are contaminated
- Option 3: detection and correction based on averaged cold counts
  - Detection and correction based on averaged cold counts (averaged over band and calibration window) to better handle noise effects
  - Works well except when all four SVs are contaminated
- These options were tested on G-ADA using data from 2011-12-05 and 2013-05-19

Comparison of different LI Correction Approach

ATMS SDR Algorithm Computed Gain Variation With Scan, Channel 9, Dataset 2011-12-05

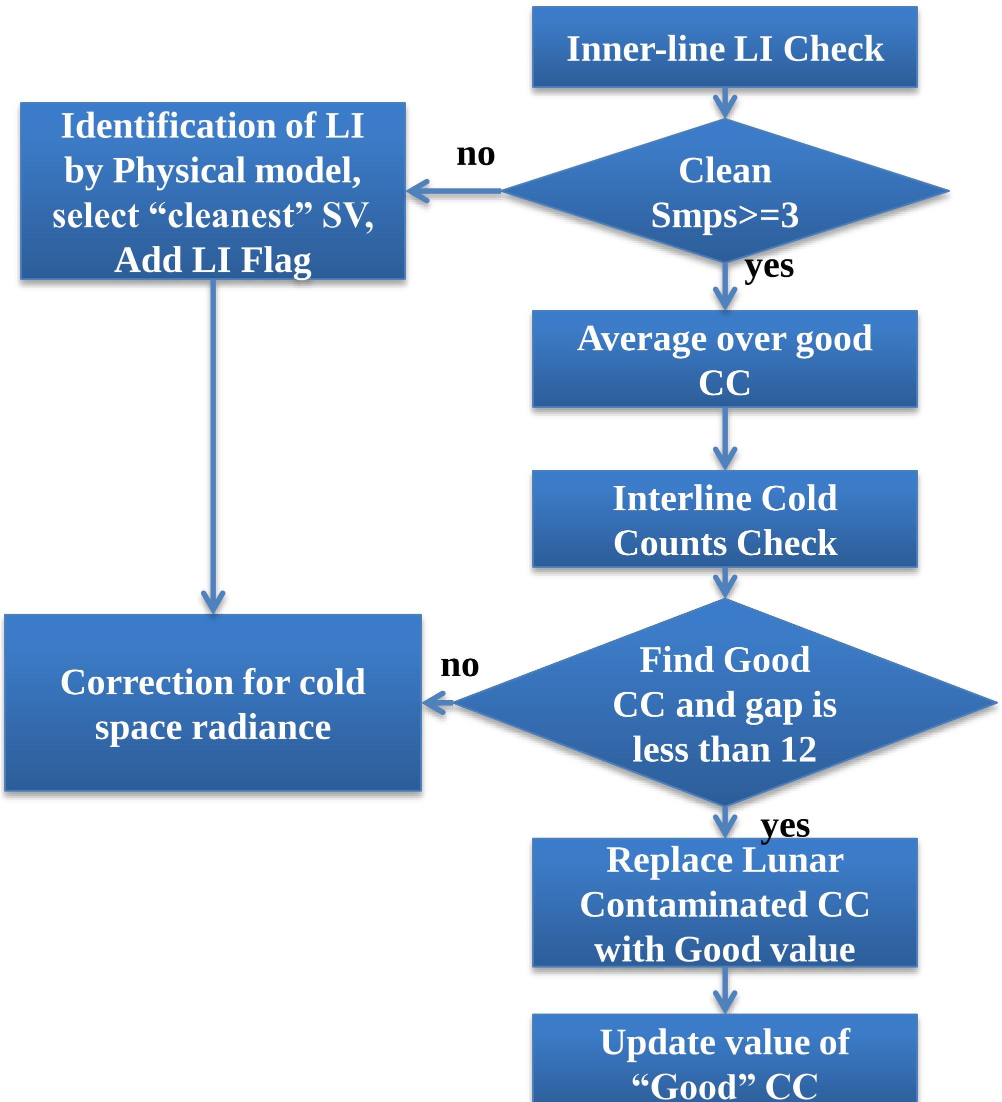


LI affected three SVs

LI affected all four SVs

Implementation of Updated LI Correction Algorithm

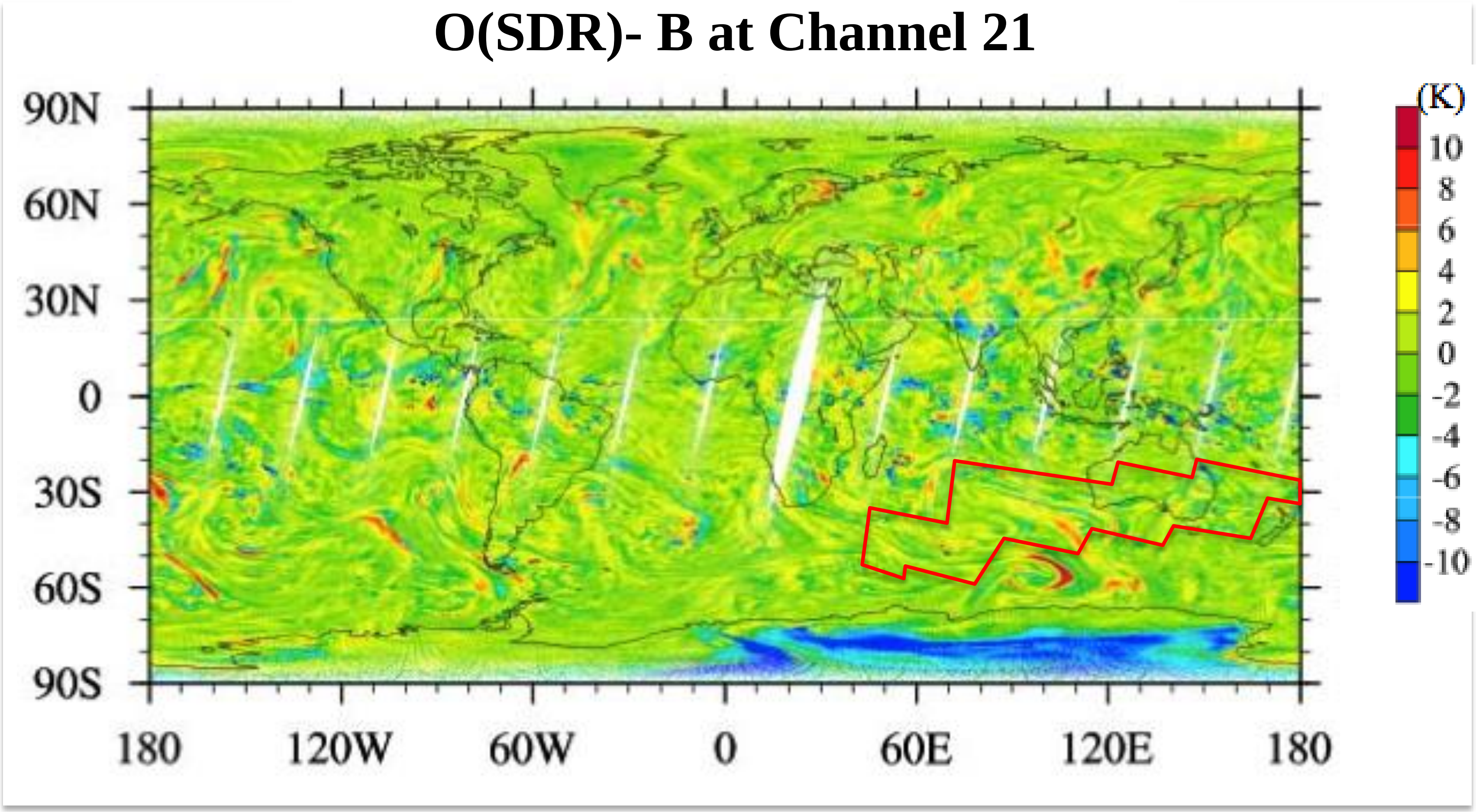
Flow Chart of Updated LI Correction Algorithm



- Replace LI contaminated cold counts with nearest clean cold counts
- Correct cold space brightness temperature increment by using updated LI correction model
- Account for possible instrument gain variations during LI
- Easy to be implemented in current operational software

Evaluation of Updated LI Correction Algorithm

Evaluation of Updated SDR at 19 April, 2013 by model simulation. After LI correction, the data gap was removed and residual error of correction is below instrument noise



Summary

- ATMS RDR dataset was re-processed on G-ADA using the latest SDR algorithm code and PCT to evaluate LI detection and correction status in current IDPS

- New physical model for LI correction was developed validated by observed lunar contaminated space view counts in different date

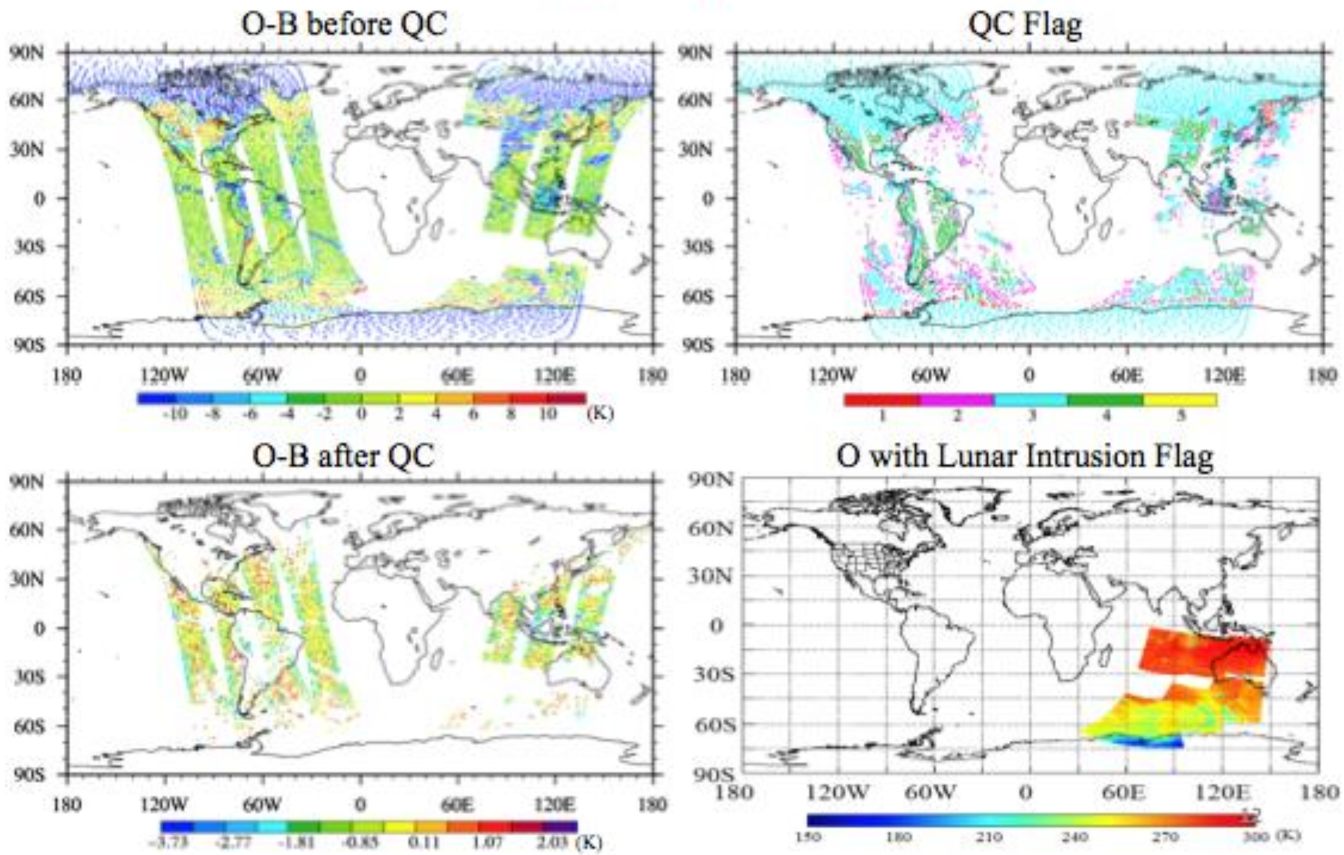
- Different approaches for LI correction was compared and tested in G-ADA, correction algorithm was validated and implemented in IDPS

- Data gap in SDR data sets was removed after LI correction, residual correction error is below the instrument noise

Backup Slides

Impact of LI in GSI

O-B of Ch. 17 (165H) before/after QC



- In the NCEP BUFR data, the data marked by lunar intrusion flag are very consistent with the data that determined lunar intrusion detection.
- In current GSI, the lunar intrusion flag is not directly used. The gross check and QC inside GSI can not completely remove the lunar contaminated data.
- The data contaminated by lunar intrusion will introduce unrealistic information into GSI as a result of the mismatch between cold counts and calibrated brightness temperatures.